Impurity seeding with dust injection in tokamak edge plasmas

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It has been observed recently that substantial amounts of dust penetrating into edge plasmas of fusion devices, either naturally occurring because of plasma-wall interactions or during dust injection experiments, can considerably affect the plasma performance due to impurities introduced by dust[1,2]. It is also possible that intentional dust/aerosol injection can be used to control edge plasma parameters, as well as to facilitate continuous wall conditioning or emergency plasma shutdown.

In present work, we explore characteristics of impurity seeding in tokamak edge plasmas in form of dust using recently coupled DUSTT/UEDGE code. The code is capable to simulate coupled transport of plasma and dust in tokamak edge self-consistently including dynamics of dust ablation, which provides impurity source in the plasma. The code validation was performed using 3-D reconstructed dust trajectories measured on NSTX with stereoscopic camera imaging technique. The dynamics and the effects on the edge plasma performance of continuously injected dust of different materials, sizes, and injection locations are modeled for various tokamaks, i.e. NSTX, DIII-D and ITER. The modeling demonstrates that dust injection in the edge plasmas of modern tokamaks with rates of several 10mg/s can significantly increase radiation power losses in the plasmas leading to substantial reduction of divertor heat load. It is also shown that achieving similar effect in ITER requires much higher rates of dust injection up to a few g/s. Different dust injection scenarios are considered including dust injection in divertor and midplane plasma regions. The impact of dust injection with different rates on plasma profiles and stability is demonstrated, which includes reduction of radial plasma pressure gradients in the edge and achieving complete divertor plasma detachment. The simulated edge plasma performance with injected dust is compared with the case of injection of equivalent amount of neutral gas. It is shown that injection of dust in ITER can lead to better assimilation of the impurities in the plasma as compared to the neutral gas injection.

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